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FINAL REPORT
2023

CYBERINFRASTRUCTURE
LEARNING & WORKFORCE
DEVELOPMENT WORKING GROUP

PRESENTED TO

U.S. NATIONAL SCIENCE FOUNDATION
ADVISORY COMMITTEE FOR
CYBERINFRASTRUCTURE

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CONTENTS

1.0 BACKGROUND & CHARTER

The Cyberinfrastructure (CI) Workforce Working Group was established to provide recommendations to the Office of Advanced Cyberinfrastructure (OAC) and the National Science Foundation (NSF) more broadly regarding CI workforce requirements (from both capability and capacity perspectives) to sustain and accelerate scientific discovery. This working group was initially part of the CI Research and Innovation Working Group. The original charter of that working group was developed at the Fall Advisory Committee for Cyberinfrastructure (ACCI) meeting in September 2019. The draft plan was to describe what constitutes CI research, recommend a CI research agenda for OAC, and recommend approaches that OAC should use to foster and nurture its research community to ensure sustainable innovations.

The Working Group would have these primary deliverables:

1. Recommend a short-term (critical, time-sensitive, high-priority in current solicitation cycle), intermediate-term (next solicitation cycle), and long-term (within 2+ solicitation cycles) roadmap for OAC CI Research, including hardware, software, and middleware for science.

2. Summarize worldwide CI Research (including China) and assess the leadership characteristics of the proposed CI Research roadmap**. A leadership roadmap is defined as one that enables leadership science.

3. A positioning of the proposed CI research in the broader context of NSF, since OAC partners with all of NSF, to advance science and engineering (S&E) research and education.

4. A description of how the next generation of researchers and practitioners can be developed to advance the research roadmap.

The discussion around the fourth proposed deliverable stated that fielding a sufficiently skilled workforce is a major challenge in realizing the future of computational science from computing on the edge to exascale and beyond. It was also agreed upon that significant investments must be made in training a new generation of scientists who are well grounded not only in their technical disciplines but are also knowledgeable about relevant computer science and applied mathematics issues.

The initial first step for determining the next generation of researchers and practitioners was to conduct a survey of multiple agencies and academic communities for research skillset needs. The following communities were to be targeted for input:

CI Users
community of domain scientists and engineers who effectively exploit advanced CI capabilities

CI Professionals
community of research CI and professional staff who support effective use of research CI

CI Contributors
community of computational and data scientists and engineers who develop new CI capabilities

After a discussion at the Spring 2020 ACCI meeting, it was decided that a new working group would be established to determine how the next generation of researchers and practitioners can be developed. The new working group was named CI Workforce Development. The participating ACCI members included Deborah Dent, Jackson State University (Chair); Susan Gregurick, Assoc. Director for Data Science, National Institute of Health (NIH); Gwen Jacobs, Director of Cyberinfrastructure, the University of Hawaii System; Ruth Marinshaw, Stanford University; and Valerio Pascucci, University of Utah.

Non-ACCI community members with experience in addressing CI research and workforce development were invited to join the team: Lisa Arafune, Director, Forge Policy Solutions; Dana Brunson, Executive Director for Research Engagement, Internet2; and Sharon Broude Geva, Independent Consultant. Two additional contributors were later added to the team: Joel Gershenfeld, Professor and Associate Dean, Brandeis University, and Alan Blatecky, RTI International.

The final charter of this working group follows:

The CI Workforce Working Group was established to provide recommendations to the OAC and the NSF more broadly regarding CI workforce requirements (from both capability and capacity perspectives) to sustain and accelerate scientific discovery.

The Working Group will produce the following deliverables:

Report of Findings: Synthesize, analyze, and summarize the recommendations of the NSF CI Workforce2020 workshop report with other existing community workforce findings. For example, the Internet2/NSF survey of Minority-Serving Institutions (MSIs), Tribal Colleges and Universities (TCUs), and Historically Black Colleges and Universities (HBCUs) and the Established Program to Stimulate Competitive Research (EPSCoR) workshop activities.

Recommendations: Develop a report with recommendations for creating a roadmap for the development of the next generation of researchers and practitioners.

2.0 DEVELOPING THE NEXT GENERATION OF CI RESEARCHERS & PRACTITIONERS

The team was inspired by the report from the Workforce in the President's Council of Advisors on Science and Technology 2020 PCAST report, **Recommendations for Strengthening American Leadership In Industries of the Future**. The key statement in the executive summary framed the context and need well: "Achieving success with the first two pillars of this report rests upon the Nation's ability to strengthen, grow, and diversify its science, technology, engineering, and mathematics (STEM) workforce at all levels—from skilled technical workers to researchers with advanced degrees. First and foremost, America must build the Workforce of the Future by creating STEM training and education opportunities for individuals from all backgrounds, STEM, and non-STEM, including underrepresented and underserved populations." From the PCAST report, the working group set out to address the development of a pathway for the next generation of CI professionals. Because of the popularity and awareness of the criticality of this topic across the CI community, the working group has been able to leverage work conducted by multiple groups in addressing the questions about how the next generation of researchers and practitioners can be developed to advance the research roadmap.

The following sections consist of contributions from members of the working group reflecting CI community reports and activities and experienced CI professionals' assessment of the landscape around these questions. Data from the following CI community reports and activities are used in making the working group's recommendations.

REFERENCES

Recommendations for Strengthening American Leadership In Industries of the Future.
https://science.osti.gov/-/media/_/pdf/about/pcast/202006/PCAST_June_2020_Report.pdf

2.1 NSF WORKFORCE 2020 REPORT FINDING ON WORKFORCE DEVELOPMENT
LISA ARAFUNE

A virtual workshop was conducted in August and September 2020 across three sessions with 100 unique attendees that focused on problems, challenges, and potential solutions to issues affecting the cyberinfrastructure/research computing and data (CI/RCD) workforce that develops software and operates and supports computing facilities for research. The final report provides a summary of the virtual workshop. It includes an overview of the workshop, a summary of the attendee selection and workshop processes, a summary of the keynote presentations, and an overview of the challenges and recommendations identified by workshop participants.

1. Recommendations for the CI/RCD Community

- Organize an "umbrella" professional organization (a "community of communities") that spans existing community groups to coordinate and agree on common standards, activities, and messaging to the public.

- Develop strategy and actions to communicate the impact of CI/RCD to institutional leadership, faculty, and students to raise the profile of CI/RCD and increase awareness of professional roles ("facings") and distinct career paths (that differ from enterprise I.T.) within the CI/RCD profession.

- Create a common set of job descriptions and career paths for CI/RCD.

- Develop a national census within the CI/RCD community to collect information on positions, pay grades, cost of living differences, and benefits to provide benchmarks for the profession, increase understanding of existing roles and compensation models for CI/RCD professionals, and improve retention and mobility options for the workforce.

- Develop a Diversity, Equity, and Inclusion action plan for the CI/RCD community.

2. Recommendations for Higher Ed Institutions and Other Research Organizations

- Create or adopt common job descriptions and define a clear career path for research computing roles with compensation and promotions models that accommodate the dual research/service roles in the workforce ecosystem.

- Create multidisciplinary programs for CI/RCD that includes the involvement of institutional information and research organizations with the goal of developing a common core curriculum for CI/RCD.

- Improve communication about the value of CI/RCD to institutional stakeholders and leadership.

- Develop sustainable funding models for research cyberinfrastructure investments such as people, software, services, and resources on campus.

- Align research computing within the organization to ensure appropriate involvement and governance from the CIO, V.P. of Research, Deans, and other constituent groups.

3. Recommendations for NSF

- Advocate the inclusion of CI/RCD professionals in the proposal process in terms of budgeting, funding effort, recognition, and project leadership appropriate for their role in the effort.

- Encourage the establishment of institutional governance bodies for research computing and encourage the establishment of cyberinfrastructure- related activities at national annual meetings attended by leadership (e.g., EDUCAUSE, PEARC, and S.C.).

- Provide seed funding through unsolicited proposals, Dear Colleague Letters (DCLs), and structured Request for Proposals (RFPs) to incentivize community action to create working groups spanning institutions that could begin working on addressing the challenges identified in the workshop.

4. Community Activities and Action Breakout Groups

During the last virtual workshop session, seven action groups were formed in response to recommendations:

- Community of Communities (activity after the workshop) - Address needs for sustainable facilitation of the professional community, education, and training, Create a blueprint for establishing a "community of communities."

- Core Curriculum Development - Address the need for formal and informal education for professionals within the research computing community.

- Career Arcs - Understand the career paths taken by successful cyberinfrastructure professionals as part of the process of defining and communicating potential career paths for research computing professionals.

- Professionalization - Discussed the need to define the profession of cyberinfrastructure and research computing that recognizes the existence of a workforce "ecosystem" instead of a "pipeline."

- CI Positions Description - Explored the steps and some of the challenges in establishing an annual Cyberinfrastructure Census.

- Diversity, Equity, and Inclusion (DEI) (activity after the workshop) - Discussed the need to create an effort with experts in DEI to generate a report with recommendations centered on DEI to help improve recruitment and retention for a diverse workforce.

- Regional Cross-Cutting Groups - Discussed the need to create regional coordination groups.

5. Insights distilled from the workshop

- A coordinated national effort is needed to improve the cyberinfrastructure and research computing workforce ecosystem for CI/RCD professionals. What is needed?

- Clear definitions of the different roles (or "facings") that reflect duties and roles in the workforce ecosystem that are adopted across the community.

- Viable career paths with a reasonable level of funding and location stability and availability of training and education necessary for advancement and upskilling.

- A concerted effort to address diversity, equity, and inclusion as a systems problem.

- Establishment of an "umbrella" organization that spans existing institutional, regional, and national organizations to advocate and coordinate actions and knowledge within the research computing community.

- More formal education and training based on a coherent body of transferable knowledge for the national community.

- An effective communication strategy to increase understanding, awareness, and acknowledgment of the essential role of research computing within the institutional research enterprise.

The entire workshop report as submitted to NSF can be found at:
https://www.rcac.purdue.edu/ciworkforce2020 2.2 Campus Research

## 2.2 COMPUTING CONSORTIUM & RCD NEXUS: WORKFORCE & CAREER ARCS
DANA BRUNSON

The work described below is supported by the RCD Nexus, an NSF Cyberinfrastructure Center of Excellence pilot (OAC 2100003). It is a Research Computing and Data Resource and Career Center that creates tools, practices, and professional development resources to support individuals and institutions. This work builds on work supported by the Campus Research Computing Consortium (CaRCC), an organization of RCD professionals developing, advocating, and advancing campus research computing and data and associated professions.

CARCC PROFESSIONALIZATION WORKING GROUP ACTIVITIES & RESULTS

The practice and process of science have changed due to the diversification of research domains leveraging high-performance computing (HPC) resources, an increased need to manage and move larger amounts of data, the prevalence of cybersecurity threats, and growing governmental regulations on data. Researchers, both within academia and outside of it, can no longer do it alone; they now rely on RCD professionals who work at the intersection of CI, research, and data and provide skills built on years of experience. The demand for RCD professionals is projected to grow. Pathways to RCD careers, however, can be "invisible" due to a lack of standardization of job titles, poorly defined job descriptions, the dispersed nature of the work across multiple units within research organizations, and inconsistent terminology to describe RCD activities.

The CaRCC RCD Professionalization working group is supporting this evolution of thought through a series of targeted initiatives. Our vision is to develop and disseminate frameworks, models, and approaches that can be used by institutional leaders in Human Resources, Information Technology, Research, and Teaching & Learning, as well as by practitioners, to support and elevate RCD roles as distinct and highly-valued career paths. Working group activities are focused on guiding conversations between Human Resources leadership and RCD leadership to effectively attract, retain, diversify, and develop the professional staff who provide RCD services. This includes broadly communicating and boosting awareness of the value of RCD careers.
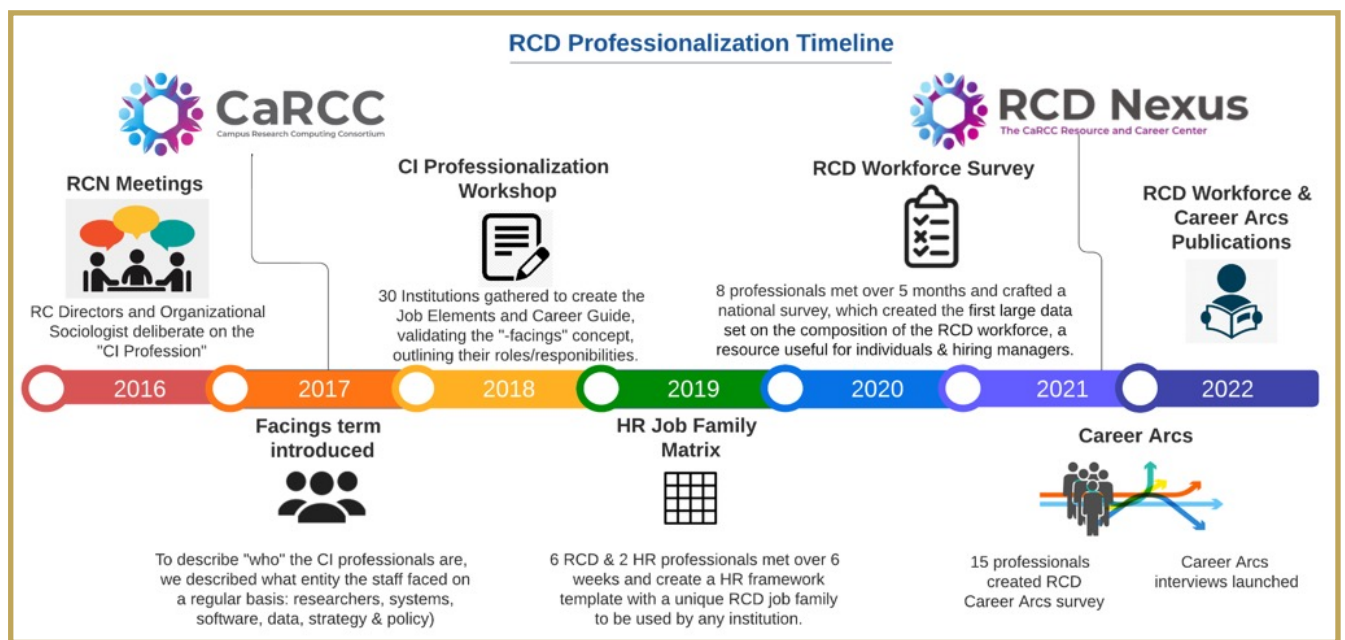
To date, this group has created three major works:

1. 2018 | **Research Computing and Data Professionals Job Elements and Career Guide** The document is organized around four broad job families (researcher-facing, systems-facing, software/data-facing, stakeholder/policy-facing), defined by the focus of the work. The first part of each of the four sections of this guide outlines the job elements in each category. The second part of each section includes the overall education, experience, and skill/competency requirements. The third part of each section covers professional development and career considerations.

2. 2019 | **H.R. Job Family Matrix** specifically for RCD Professionals that can be used by a range of institutions to properly classify RCD Professional roles.

3. 2020-2021 | **RCD Positions survey tool** was designed, tested, and implemented to conduct a national survey of the RCD workforce. A group of RCD professionals who wanted to work on this was formed at the NSF Virtual Workshop on the Research Innovation Workforce for Cyberinfrastructure.

The following are excerpts from the first publication[1] on the results from the RCD Workforce Survey:

This is the first survey to quantitatively measure the broad RCD workforce and the unique characteristics, skills, and backgrounds of its members. The demographic diversity of the RCD workforce falls short of that of university faculty and of the broader U.S. mathematical and computational workforce; there are, however, many pathways by which the diversity of the profession could be improved. The RCD workforce is highly educated but would benefit from recruiting individuals from a wider range of educational domains, especially social science. A large majority of respondents feel included and welcome in the field and feel their work is valued by those they work with, but there is work to be done conveying the value of RCD work to institutional leaders and ensuring that those from all demographic backgrounds feel equally welcome in the field. Overall, the survey results support prior qualitative assessments of the challenges the RCD field and those in it face to recruit and retain talent, develop career pathways, and grow the profession.

Additional papers on parts of the survey not covered here are underway, including an analysis of job responsibilities and compensation (which were not covered here) and further breakdowns of survey responses for different groups of RCD professionals. The intention is to repeat the survey every few years to track the progression of the workforce and profession as they evolve. While this survey captured information about a significant proportion of the academic RCD workforce, future surveys should specifically target R2 universities and academic computing centers, and institutions that are not currently reached by community email lists to broaden participation and build an increasingly representative sample of the academic RCD workforce. Beyond academia, few RCD professionals from government and corporate institutions participated. Identifying such individuals and connecting academic and non-academic RCD communities is likely to be challenging as the majority of those working in academic RCD positions do not have RCD experiences outside of academic institutions. Developing such connections will be part of the evolution of the RCD profession.

This data provides a foundation against which to measure the progress of community efforts in areas such as recruiting professionals who reflect the diversity of the U.S. research community and population, developing common job descriptions and titles, supporting professional development, and improving institutional recognition for the value of RCD work. The RCD community has many highly engaged members, and we have the opportunity to shape the development of this new profession to support those in it and welcome new people to it. Data on the workforce will allow us to better assess this work.

[1] Christina Maimone, Scott Yockel, Timothy Middelkoop, Ashley Stauffer, and Chris Reidy. 2022. Characterizing the US Research Computing and Data (RCD) Workforce. In Practice and Experience in Advanced Research Computing (PEARC '22). Association for Computing Machinery, New York, NY, USA, Article 27, 1–7. https://doi.org/10.1145/3491418.3530289

CARCC CAREER ARCS WORKING GROUP ACTIVITIES & RESULTS

Research Computing and Data (RCD) professionals play a crucial role in supporting and advancing research that involves data and/or computing; however, there is a critical shortage of RCD workforce, and organizations face challenges in recruiting and retaining RCD professional staff. It is not obvious to people outside of RCD how their skills and experience map to the RCD profession, and staff currently in RCD roles lack the resources to create a professional development plan. To address these gaps, the CaRCC RCD Career Arcs working group has embarked upon an effort to gain a deeper understanding of the paths that RCD professionals follow across their careers. An important step in that effort is a recent survey the working group conducted of RCD professionals on key factors that influence decisions in the course of their careers. This survey gathered responses from over 200 respondents at institutions across the United States. A recent ACM PEARC22 paper[2] presents our initial findings and analyses of the data gathered, and we summarize those findings below. We describe how gender, career stage, and RCD roles impact the ranking of these factors. While there are differences across these groups, respondents were broadly consistent in their assessment of the importance of these factors. In some cases, the responses clearly distinguish RCD professionals from the broader workforce and even other Information Technology professionals.

The primary objective of the survey was to identify factors that attract professionals into the field of research computing and data, factors that influence their career advancements or changes within the RCD field, and factors that cause them to leave and pursue other fields. For a number of questions, we aggregated all the results to rank the factors and then considered the responses through the lens of various RCD roles using the CaRCC Facings model[3]. In general, we saw relatively little variation across the Facings, which may in part be due to the fact that respondents could indicate more than one facing as a part of their job. Indeed, only 16.3% of respondents indicated a single facing, with Software Facing as the least likely to be distinct. All five Facings were marked by 18.3% of respondents, and after this, the most common patterns were Research Facing + Strategy and Policy Facing (7.7%) and all except Strategy and Policy Facing (6.7%).

Disciplinary backgrounds range from arts and humanities (14%), engineering, computer and information sciences (57%), life and health sciences (13%), mathematical and physical sciences (32%), social, economic, and behavioral sciences (8%) and other (4%) (respondents could select more than one, so percentages sum to more than 100%). The gender distribution of the survey respondents was 34.6% female; 58.5% male; 3.8% gender non-conforming/ genderqueer, non-binary/third gender or other; and 3.1% preferred not to state. Most respondents were 35 to 54 years old (57%), with the rest skewing slightly older. A majority (93%) of our respondents have worked in academia, over half have worked in the private sector, and quite a few have worked at federal labs (10%), for the government (20%), or for non-profits (22%).

Research Finding: What Advancement Means Across Career Stages

We posed the question, "What does advancement in your current RCD role mean to you?" and asked respondents to rank at least 5 of 12 factors. The rankings are presented in Fig. 1, sliced by RCD Career Stage. Overall, the data show how important *recognition* is to RCD Professionals (this factor was ranked well above all others, and influence was also in the top three. The second highest was *salary and benefits* (although this was the top factor for early career professionals). Somewhat lower in the rankings, there is a cluster of professional development factors (and early career respondents value these more than those with more experience).

[2] Chaudhry, S., Pazouki, A., Schmitz, P., Hillery, E., and Kee, K. 2022. *Understanding Factors that Influence Research Computing and Data Careers.* In Practice and Experience in Advanced Research Computing (PEARC '22). Association for Computing Machinery, New York, NY, USA, https://doi.org/10.1145/3491418.3530292. Best Paper, Workforce Development, Training, Diversity, and Education track, and Phil Andrews award (granted to a manuscript deemed to be the most impactful in practice of research computing).

[3] https://carcc.org/facings

Of note is that "Progressing up a series of titles" and "Rising to management" both rank quite low overall, although "Rising to management" is comparatively more important to early career respondents and much less important for advanced career respondents. Also worth noting is that although respondents ranked salary quite high in their definition of Advancement, they ranked it much lower in importance as a factor motivating them to switch jobs (see next section). It seems that people recognize that salary is often a marker of advancement, but it is not as important to RCD Professionals in making decisions about their careers.
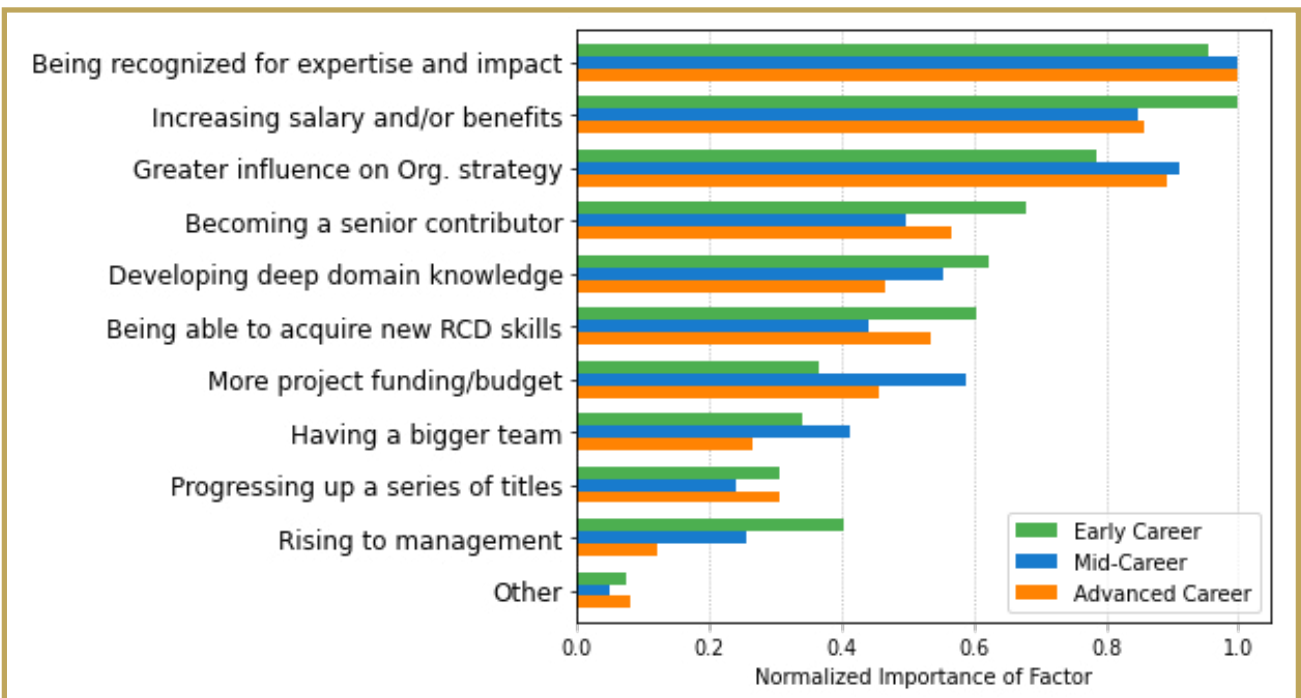

FIGURE 2. *Ranking of factors defining "Advancement," sliced by RCD Career Stage.*

Research Finding: The Importance of Factors Motivating Job Changes

One of our goals was to understand why people change jobs over the course of their careers. We asked: "How important were the following factors in motivating you to make a previous job transition, or that would motivate you to consider a future job transition to or within the RCD field (i.e., to a new RCD position or role)" using a 5-point Likert scale (see the full paper, Fig. 3). The top three factors are associated with impact and personal growth, i.e., opportunities for a more meaningful contribution (1), professional development (2), and joining a more innovative organization using cutting-edge tools (3). The next two factors in order were more practical: more flexible hours and/or a better work-life balance (4) and a higher salary (5). It is worth noting that ranking salary 5th, the ability to work remotely 10th, and better benefits 12th stands in contrast to the current discussion of how many workers, in general, are leaving jobs in search of higher pay, better benefits, and remote work opportunities. Relocation is also cited as a major reason people are changing jobs these days, but it was the lowest-ranked factor in this survey.

We saw a broad agreement across the Facings, although Strategy and Policy Facing roles put much more weight on the opportunity to have more influence and somewhat more on opportunities for promotion or advancement, for greater community engagement, and to relocate. Similarly, we saw relatively little divergence by Career Stage, with a few exceptions. The ranking of opportunities to have more influence increases with career experience, while the interest in working remotely decreases with career experience. Mid-career professionals are more likely to move for a better cultural fit or due to a loss of funding for their position, but they are much less interested in gaining experience in other domains. Early career professionals are the most interested in relocation, although it is still ranked low for them.

Research Finding: The Role of Gender in the RCD Profession

We had 34.6% of women respondents in our survey, with the majority in researcher-facing, data-facing, and strategy & policy-facing roles. Women represented less than one-fourth of Software-Facing and Systems-Facing roles and are markedly under-represented in these roles. Among respondents, there are far fewer women than men in an advanced career stage (see Fig 2.). This gender imbalance may be due to female attrition and/or women not having worked long enough in RCD roles to reach the advanced stage and needs further exploration.

FIGURE 2. *Genders by RCD career stage.*
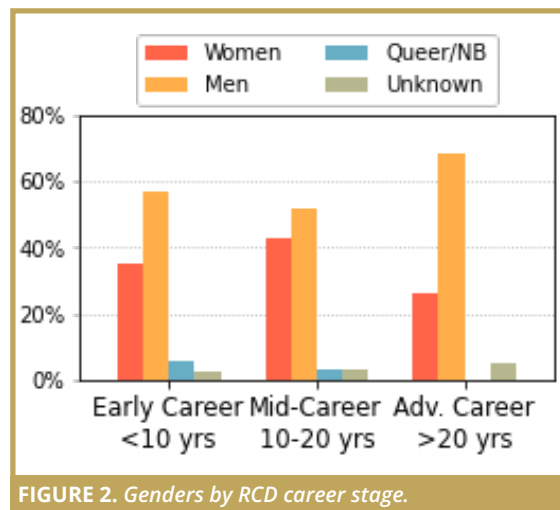
Among respondents, men were much more likely to believe that technical skills, projects they had worked on, and their years of experience were important in getting hired into their RCD roles, while women were much more likely to believe that interpersonal and communication skills, leadership skills, and a referral from someone were important. However, when observed from the perspective of a hiring manager, both men, and women consider technical skills to be the most important factor for hiring people into an RCD role (see the full paper, Fig. 4). Compared to men, female hiring managers place greater importance on interpersonal and communication skills; experience in understanding of research projects; previous projects that candidates had worked on; degree and domain of degree; years of overall experience; places worked in the past; and technical certifications. On the other hand, male hiring managers rely more heavily on referrals from someone and experience working with a group as a student.

The top five factors that people consider for switching jobs were the opportunity for a more meaningful contribution, the opportunity for professional skills development, the opportunity to join an innovative organization, better work-life balance, and higher compensation. An interesting observation here was that men rated better work-life balance slightly higher than women while women rated better compensation slightly higher than men. Women were also more likely to consider switching jobs to join a team with a better culture fit or in response to being inspired or convinced by someone.

The top three important defining factors for career advancement for all people were recognition for expertise and impact, increasing salary and/or benefits, and greater influence on organizational strategy. However, it is to be noted that women consider recognition and impact to be a far more important factor than compensation, while men rated better compensation and recognition/impact as equally important. Men were also more likely than women to rate becoming a senior contributor, developing deep domain knowledge, and being able to acquire new RCD skills as factors associated with career advancement.

We see a clear need to attract more women into the RCD field, especially in systems and software-facing roles. In addition, there is a need to retain and develop women from mid-career into advanced-career levels.

CONCLUSION & FUTURE WORK

This work is part of a larger project to describe different possible paths for RCD roles and to help to hire managers and recruit and retain people in these roles. In the next phase of our work, we are looking to gather deeper individual narratives through a series of interviews of RCD professionals in various phases of their RCD career journeys. Our hope is that these narratives will illuminate possibilities for individuals considering or already in RCD careers, as well as helping hiring managers understand fruitful domains and populations for recruitment. The survey questions and response data presented here will be used to refine our interview questions.

2.3 EPSCOR EXPECTATIONS ON WORKFORCE DEVELOPMENT
GWEN JACOBS

Research Cyberinfrastructure (CI, a.k.a. Research Computing and Data (RCD)) is changing at an accelerating rate, while the breadth of fields and disciplines that depend on these technologies is expanding and increasingly diverse. This poses significant challenges to academic institutions as they try to effectively assess and plan for the necessary support infrastructure to keep pace with the needs of researchers. EPSCoR jurisdictions have historically underinvested in the CI resources and services required to drive forward data and compute-intensive science (Hill, 2012). This has created an uneven distribution and availability of CI across the nation (Hill, 2012; Blatecky, et al., 2019). However, the degree of this inequality remains unclear because data is lacking on CI availability across EPSCoR jurisdictions and institutions. The 2022 EPSCoR CI workshop is working to address this by generating a unique baseline and compiling aggregate data concerning EPSCoR jurisdictions' current CI capabilities, gaps, and priorities in EPSCoR jurisdictions. These data will improve knowledge of CI distribution and access, serving to increase discussion at local, regional, and national levels.

This report presents an analysis of the 2020/21 aggregated data from 15 EPSCoR institutions that completed Research Computing and Data Capabilities Model (Schmitz, et al. 2020) assessments in 2020 and 2021. These institutions represent 11 states and U.S. territories and include R1, R2, and other Carnegie Classifications. The RCD Capabilities Model allows institutions to assess their current capabilities and provides structured input for strategic decision-making using a shared community vocabulary. The model presents roughly 150 capabilities (in the form of questions) structured around five "Facings" that are increasingly used as a means of characterizing the roles of people who support CI/RCD: Researcher-Facing, Data-Facing, Software-Facing, System-Facing, and Strategy and Policy-Facing. The Assessment Tool also allows institutions to mark specific capabilities as priorities. The resulting dataset provides important insights into the state of support for RCD at both summary and granular levels (Schmitz, 2021).

For the community of institutions in EPSCoR jurisdictions, the dataset also shows clear gaps in coverage relative to peers in non-EPSCoR jurisdictions. While patterns revealed in the data may be unsurprising to some, it is important to have this baseline – both to corroborate the experience of leaders at these institutions, as well as to provide a detailed framework for discussion among EPSCoR institutions on how best to support research in their jurisdictions. It is our hope that the report provides a basis for fruitful discussions in the March 2022 preliminary workshop, as well as the Fall 2022 workshop to be held in conjunction with the national EPSCoR conference[1].

While the relatively small number of participating institutions and the wide variance among them means that most of our conclusions are not statistically significant, the main described resonate with many members of the community who have reviewed the results and are compelling enough to merit consideration. **Some highlights of what the data indicate include**

- EPSCoR institutions lag their non-EPSCoR peers in CI/RCD capabilities across the board, with the widest gaps in the Data-Facing and Researcher-Facing areas.

- EPSCoR institutions provide services at a less robust operational level than non-EPSCoR institutions and are less able to provide services to all researchers across the institution.

- The top priorities of the contributing EPSCoR institutions are mostly in Data-Facing, Software-Facing, and Researcher-Facing topics, although the fourth-highest priority is the need for more strategic planning.

- An interesting pattern emerged between the 2020 dataset and the combined 2021 dataset in which half the 2020 contributors repeated their assessment. For the repeating institutions, average Strategy and Policy-Facing coverage increased from 44% to 60% – a remarkable 35% in one year.

REFERENCE:

Schmitz, P, Bayrd, V, Strachen, S and Jacobs, G 2022 A Baseline of EPSCoR Research Capabilities. Highlights from the 2020/2021 RCD CM Community DataSet. Technical Report RCDNexus-TR 2022.2 https://doi.org/10.5281/zenodo.6395203

2.4 THE NEED FOR WORKFORCE DEVELOPMENT FOR CREATING & SUSTAINING A LEADERSHIP WORKFORCE FOR CI
SHARON BROUDE GEVA

CYBERINFRASTRUCTURE LEADERSHIP WORKFORCE DEVELOPMENT

Workforce development has become an essential topic of discussion in the CI practitioner community over the past decade, and its importance is well-accepted. The discussion, however, has been primarily focused on the development of CI staff for system administration, facilitation, research software engineering, and other crucial technical roles. Less attention has been paid to the need to develop CI leadership, without which CI organizations cannot exist.

We define "Leadership" in this case as the highest level of staff in advanced research computing organizations, or those who are at the executive level of the organization, whether that is their only responsibility or it is carried out alongside other technical or academic responsibilities. Typically, they hold a director title or, in some cases, an Assistant Vice President title. These leaders must possess a mix of skills that are very different from those of most information technology (IT) leaders or those of other "Science Executives." Many of these skills stem from their academic training and from their experience with CI, but there are aspects of their jobs that the majority of others on campus at their administrative level do not need to be engaged in, such as advocacy for funding and proof of return on investment (ROI) to senior administration, or serving on funding agency review and focus panels, for example.

Why are these leaders important to the sustainability of a CI ecosystem?

1. On campus, these are usually the people in charge of the technical CI resources and operations of the CI services group/s but also in charge of the vision for CI on campus and the advocacy for the needs of computational researchers.

2. Unlike other IT groups, even if part of a larger division on campus, the CI organization/s are usually self-contained and have to address many specialized research needs such as storage and computational resources, network, expert consulting, etc.

3. In the broader picture, these are the people who form one of the bridges between funding agencies and computational researchers by understanding the current computational research needs as well as the upcoming challenges.

4. They are in the trenches and on the front line of campus CI, understanding the impact of agency policy and gaps in solicitations while serving as an expert group for peer review, helping make many of the CI resource projects funded by agencies and foundations possible on campus even if they are behind the scenes of proposals, and increasingly providing the leadership for innovations in campus and national resources.

All of this is not what is expected of someone at a typical director level on campus, which makes it much harder to train, mentor, recruit, and sustain this workforce. Anecdotally, this group tends to be closer to retirement than many of the other IT leadership groups or faculty groups.

The pipeline paradigm rarely works for this group. Most of them are on a one-off career trajectory. Even in large R1 institutions, there is rarely more than one person engaged in this work. Even at R1s, most have never had a deputy or second in command who could just be mentored while they shadow the current director and, in time, take over the position.

The outcome of this is a situation where the national landscape of center leadership resembles a game of musical chairs. In this case, though, there are far more empty chairs than people to fill them. Without a program to evolve new participants in this game, every transition in CI leadership across the country either becomes a zero-sum game (one institution gains, the other one loses), or people who are unprepared are catapulted into these leadership positions from CI technical positions or in some cases even from technical management of non-CI groups, without training. This type of expertise does not translate well from industry to academia, unlike many other IT positions. It works out sometimes but doesn't always end well for the institution.

Notably, NSF has funded a small number of projects aimed at helping solve this ever-expanding problem. **Prominent examples for people who are already in leadership roles include:**

- Managing Cyberinfrastructure Centers in a Demanding Era: The Development of Science Executives, NSF CI Team Award #1240160, P.I. - Nick Berente, Co-PI John King (2012-2016 $288,671) with the participation of Joel Cuthcher Gershenfeld, James Howison, and Susan Winter

- Cyberinfrastructure Leadership Academy, NSF Award #1649475, P.I. - Henry Neeman (2016-2022 $49,300)

What is missing is a cohesive program to guarantee a full pipeline of leaders that will not only support the campus needs for CI leadership but will also support the national and agency needs for this type of workforce. This requires funding but hinges on the transition of expertise and experience from one generation to the next and is crucial to forming a diverse, sustainable, and expanding leadership cohort nationally.

2.5 MINORITY SERVING CYBERINFRASTRUCTURE CONSORTIUM STAKEHOLDER SURVEY
DEBORAH DENT

BACKGROUND

The Minority Serving Cyberinfrastructure Consortium (MS-CC) was established in 2018. The Consortium emerged from an NSF-funded research coordination network (RCN) pilot project (the "Project") that was awarded through Clemson University (NSF OAC #1659297 "CC* Cyber Team: Cyberinfrastructure Empowerment for Diverse Research, Scholarship, and Workforce Development (CI Empower)"). Following the completion of the grant, a group of twenty attendees decided to continue the discussions and create the MS-CC to develop and discuss a potential consortium among HBCUs and other Minority-serving Institutions. The central theme has been "We can do more together than we can alone."

STAKEHOLDER SURVEYS

In partnership with Internet2 and Waymark Analytics, the MS-CC conducted the 2020 Stakeholder Survey, which surveyed presidents, administrative leaders, I.T. groups, faculty, and staff at nearly 485 HBCUs and Hispanic Serving Institutions (HSIs) in November 2020. The goal of the survey was to collect a critical data set for guiding priorities and enabling collaborative initiatives and imperative cyberinfrastructure improvements that may also require funding and grants. TCUs conducted a similar survey through an effort led in partnership with the American Indian Higher Education Consortium.

The survey was designed to collect current data and computing infrastructure landscape, determine needed funding, and establish priorities for HBCUs, TCUs, HSIs, and other minority-serving institutions. There were 291 respondents across 144 institutions (44 HBCUs, 63 HSIs, and 32 TCUs).

Dominant responses centered on the need for high-speed broadband, access to cloud resources, and high-performance computing capabilities.

The report indicated that the areas of science and engineering, workforce development, energy and environment, social science, and culture were high priorities associated with computing and data among the respondents. However, they found them difficult to attain. **As a result of the survey, the following focus areas targeting CI workforce development were established:**

- Developing shared curriculum resources to be adapted for use among the MS-CC campuses, with input from industry professionals on key topics, including cybersecurity, data analytics, data curation, cyberinfrastructure, networking, and related topics.

- Developing and delivering network engineer training, linked across MS-CC campuses with co-op and internship opportunities.

- Developing a talent pipeline of students from MS-CC campuses to fill cyberinfrastructure positions that are opening on a continuing basis as the staff is being hired away by the private sector.

Two additional surveys were conducted following the first one. All three determined that limited workforce development opportunities and cyberinfrastructure capabilities are the two most significant barriers to achieving their cyberinfrastructure goals.

FUNDING & PARTNERSHIP WITH INTERNET2

As a result of the survey findings and, in an effort to address CI workforce development, the MS-CC, in partnership with Internet2, was awarded a Cyberinfrastructure Center of Excellence (CI CoE) Pilot program grant (NSF OAC #2137123 "CI CoE: Demo Pilot: Minority Serving Cyberinfrastructure Consortium"). With this grant, the MS-CC and Internet2 will provide researchers, professional staff, and students from historically Black colleges and universities (HBCUs) and tribal colleges and universities (TCUs) with programs and services that address their cyberinfrastructure needs. While the initial focus of this grant is to advance cyberinfrastructure on campuses with definite needs through a partnership model, possibilities exist for additional opportunities to expand the collaborations and support among other minority-serving institutions (MSIs).

In September 2022, the MS-CC and Internet2 were awarded a grant (NSF OAC # 2234326 "21st Century Research-Cyberinfrastructure for MSIs through the Minority Serving - Cyberinfrastructure Consortium (MS-CC): A phased approach to engage the Missing Millions") to support the acceleration of cyberinfrastructure- centric research capacity at HBCU and TCU campuses. This new grant builds on earlier work by the MS-CC and Internet2, including an NSF Cyberinfrastructure Center of Excellence Demonstration Pilot to provide researchers, professional staff, and students from HBCUs and TCUs with programs and services that address their cyberinfrastructure needs.

CONCLUSION

Work has begun to address the barriers revealed by the stakeholder mapping surveys that have prevented HBCUs, TCUs, HSIs, and other MSIs from achieving their primary research computing and data (RCD) needs. The surveys and workshops sponsored by the grants have provided data and empirical evidence that show what the immediate cyberinfrastructure needs are and what barriers are preventing campuses from achieving them. Even though we are still in the initial stages, the grants and partnerships are examples of progress towards narrowing the digital divide, negatively impacting underserved institutions, and allowing opportunities for members from HBCUs, TCUs, HSIs, and other MSIs to participate in and contribute to the CI/RCD community.

The PCAST report stated that attention to workforce development in all areas and at all levels is of great importance. The efforts described in this section are examples of targeted efforts directed at identifying and developing the CI workforce and advancing research computing and data resources at underrepresented institutions.

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2.6 ENVISIONING A 21ST CENTURY PROFESSIONAL SOCIETY FOR RESEARCH COMPUTING & DATA PROFESSIONALS
JOEL CUTCHER-GERSHENFELD

In the current digital era, there is an emerging need for a professional society serving RCD Professionals, including Campus Champions, CI Facilitators, Research Software Engineers, and other RCD/CI Professionals. These are the people that serve as the interface between researchers and the infrastructure and technology that enables their research, creative, and/or scholarly activities. The work is complex, the pace of change in technology is accelerating, and a professional society has the potential to lift up and support the work of RCD professionals.

To help advance the RCD profession, a stakeholder "pulse" survey was conducted by the CaRCC with the Extreme Science and Discovery Environment (XSEDE) community engagement initiative and with WayMark Analytics (an NSF I-Corps organization) in May 2022. A total of 204 individuals responded, most of whom were research computing leaders (CIOs, VPRs, research computing directors (32%) or research computing facilitators (27%), with the balance in research data roles (9%), HPC computing, network, and storage roles (8%), software engineering

roles (4%), and other roles. Most respondents were university-based (85%), with some in nonprofit settings (7%) or Federal national labs (3%). Demographically, the mix of respondents points to a need for broader diversity in the profession. Most respondents were male (73%), with the balance female (24%) and with non-binary gender identities or preferring not to say (3%). The majority were also white (80%), with the balance Asian (7%), Black (3%), Hispanic (3%), and in other categories or preferring not to say (8%).

It is also of note that the landscape includes a wide range of consortia and initiatives in which these respondents had connections, including the CaRCC (67%), the Campus Champions (52%), EDUCAUSE (37%), Extreme Science and Engineering Discovery Environment (XSEDE) (37%), Internet2 (30%), the Carpentries (software, etc.) (27%), Coalition for Academic Science Computation (CASC) (20%), the Virtual Residency (17%), the Open Science Grid (16%), Women in HPC (WHPC) (15%), and many others. Even with these many connections, there was a clear indication of the need for more progress with professionalization.

Importantly, the priorities were not for traditional certification of professional capabilities and a journal. **Here is how various professional functions were ranked (and the percentage placing an item among their top three priorities):**

1. Educational and professional development opportunities (75%)

2. Access to a network of other RCD professionals for assistance (77%)

3. Advancing diversity, equity, and inclusion in the profession (51%)

4. Forming working groups to address priority issues for the profession (46%)

5. Coordination with other professional societies and consortia relevant to research computing and Data (36%)

6. Certification, badging, and other recognition of professional capabilities (36%)

7. Hosting a professional journal (7%)

The stakeholder survey took the "pulse" on 11 indicator issues, asking in each case how important the issue was (on a scale from "0" for "not important" to "10" for "very important, with responses below from 7 to 10 as important or very important) and how difficult it would be to advance this issue (on a scale from "0" for "very difficult" to "10" for "very easy" with data below on responses from 0 to 3 as difficult or very difficult)

One of the issues was seen as very important and not that difficult, which is overall support for a network of professionals:

• *Access to a professional network of RCD professionals.*

– **93%** important or very important; **21%** difficult or very difficult

. . . .

Two of the issues had clear alignment as both important and not that difficult — what might be called early priorities:

• *Awareness of career opportunities associated with research data and computing support.*

– **81%** important or very important; **24%** difficult or very difficult

• *Documenting and supporting aspirational career paths for RCD professionals within higher education.*

– **82%** important or very important; **48%** difficult or very difficult

Three of the issues were both important and difficult – clear pain points in need of attention:

- *Advancing diversity, equity, and inclusion among RCD professionals.*
  - **82%** important or very important; **75%** difficult or very difficult

- *Protecting RCD professionals from burnout on the job.*
  - **85%** important or very important; **64%** difficult or very difficult

- *Communication and coordination among RCD professional organizations and consortia.*
  - **79%** important or very important; **54%** difficult or very difficult

Two of the issues were matters on which there was alignment around what not to do:

- *Each cyberinfrastructure professional organization or consortia "staying in its lane" and not "stepping on the toes" of others.*
  - **22%** important or very important; **45%** difficult or very difficult

- *Controlling entry into the profession in ways similar to what medical and legal professional societies do.*
  - **22%** important or very important; **55%** difficult or very difficult

Finally, there was a mixed picture on three of the issues:

- *Documenting and supporting aspirational career paths for RCD professionals in the commercial sector.*
  - **55%** important or very important; **34%** difficult or very difficult

- *Advocacy on behalf of the RCD professional community.*
  - **75%** important or very important; **44%** difficult or very difficult

- *Groups of cyberinfrastructure professional organizations or consortia hiring joint staff as shared resources (e.g., subject matter experts, communication professionals, and other shared services).*
  - **59%** important or very important; **68%** difficult or very difficult

What emerges from this stakeholder "pulse" survey is clear support for professionalization, but with an emphasis on networking, community building, career advancement, diversity and inclusion, and preventing burnout. There is not support for each organization or Consortium in this space "staying in its lane," and there is not support for controlling entry in the profession in the way that medical and legal professional societies do.

At the conclusion of the "pulse" survey, the respondents were asked if there were anything else they would like to share. As one of the respondents to the open-ended question noted, the traditional model of professionalization is not what they seek:

> "*Putting up barriers to access is a terrible idea given the highly varied background of R.C. professionals and is one of the reasons other "professional" societies come off as exclusionary, staid, not agile, boring, overly academic, behind the times, stodgy, not innovative. There needs to be more emphasis on the society, community aspects and the professionalism will follow (with effort of course).*"

Another echoed the same sentiment and pointed to the implications for diversity:

"The gatekeeping and barrier-building and blockading in the last several questions seem both like a fundamentally terrible idea and like a direct cause of the diversity problems the field already suffers from."

In contrast, there was great appreciation for learning and connecting with others at a time of accelerating technological change:

"With so many new technologies in computing, storage, software, frameworks, etc., I find it very important to have a way to network with peer institutions to share experiences and learn from each other. Some of us don't have a lot of resources to explore many novel ideas and systems, so it is very helpful to see what bigger HPC centers are doing and get some guidance and ideas. Thank you for your work in support of RCD."

Another respondent noted that some of the work of research computing and data professionals is more relevant to qualification standards, but even there is a concern with creating barriers to entry:

"Going in the direction of a fully-fledged professional qualification will stifle entry. Perhaps longer term, a certification will work, but in the shorter term, let's help people join. There are some areas where thinking, management, and writing skills combined with the correct mindset will be enough. There are other specialized areas (running HPC) where the skill set is very specific and where a high degree of proficiency is needed. Even so, a professional qualification will prevent skilled people migrating into the area."

At the same time, there are internal alignment challenges, such as advancing the professional identities around research data and computing work:

"In my situation, the biggest challenge is convincing our RCD professionals that they are RCD professionals -- they are clinging to their old status as I.T. professionals and preventing us from moving forward by refusing to specialize."

Similarly, not everyone is pointing to a new form of professionalization, as this respondent indicated:

"I am in a small minority that believes that the field needs a proper professional licensure process that includes training and practical apprenticeship. I believe this needs to be at the level of professional investment as becoming a civil engineer or medical professional. I have not found many people who agree with this, though...."

In conclusion, one final comment by a respondent illustrates both the importance of the work and the risk of not valuing the work:

"I feel it is critical and long overdue for RCD professional roles to be recognized and valued. In our group, many of us feel we are conveniently used with no clear career advancement path forward, and even though we play important roles at our university, no one seems to know we even exist. Without any connections to RCD professionals from other institutions/companies, our work gets mundane, and we are often unaware of opportunities outside our immediate environment. Unless this gradually changes, most of us will feel burned out."

2.8 DEMOCRATIZING COMPUTATION AND DATA TO BRIDGE DIGITAL DIVIDES & INCREASE ACCESS TO SCIENCE FOR UNDERREPRESENTED COMMUNITIES
ALAN BLATECKY

The "Missing Millions" report funded by OAC involved a total of 15 focus groups and six individual interviews that were conducted with 88 key stakeholders of research CI investments. The intent of the study was to more fully identify opportunities to democratize computation; bridge digital divides in ways that would better reach the missing millions, and help create a more diverse workforce.

Key findings in this report begin with the identification of many barriers that limit access to research data and computing, including cyberinfrastructure being undervalued and a culture that is not sufficiently inclusive. Focus groups consistently observed the need to support building science capabilities with underrepresented communities as well as supporting nontraditional approaches and disciplines to enable faculty and students the ability to meaningfully engage in science and research. These efforts to broaden the scientific and technical workforce, in turn, require sustained programs to extend beyond the normal NSF 3-year grants awards.

THE REPORT HIGHLIGHTED SIX KEY TAKEAWAYS

1. Access is essential, but not sufficient — that is, while everyone needs to have access to critical computing and data resources, the opportunity is essentially meaningless for people who don't have adequate expertise and support to effectively use or leverage these resources.

2. Most funding programs assume a level playing field so that everyone can compete — however, how can people effectively compete or play the game if they don't know what the rules are? "Don't teach me how to fish; teach me what it means to fish." Funding and support programs need to include training and education on how to conduct research and engage in science.

3. Developing science and research ecosystems with underrepresented institutions and communities is critical to broadening the workforce. Students and faculty need to work with others in their communities to obtain a sense of belonging – to see people like them that are doing science and research, developing skills, and sustaining their interests. "If I'm going to be it, I need to see it."

4. Broader pre-engagement approaches are essential to building a diverse workforce – targeted apprenticeships, internships, work-study programs, and fellowships. And invitations from significant science projects and conferences need to be extended to underrepresented students and faculty to directly engage and participate in the conduct of science. By participating in these apprenticeships and internships, they have the opportunity to learn more about the larger science community and become active members.

5. Recognition of the value that underrepresented communities can bring to the table to address major scientific and social challenges (environmental, health disparities, resource issues, climate change) facing the world – not as providers of data but as active collaborators in the research enterprise. "Nothing about us without us"

6. Efforts and programs require sustained investment and support; standard 3-year grants are not adequate to address building communities or developing science ecosystems for underrepresented institutions and campuses. Programs need to be more intentional and include a focus on involving community stakeholders.

The report also noted a sense of urgency and a call to action to reduce the growing digital divide and broaden the national technical and scientific workforce.

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3.0 SUMMARY

With the increasing demand for RCD professionals, the working group has observed from the various efforts reviewed in this study that significant attention is taking place on developing the next generation of CI researchers and practitioners. We have identified challenges and opportunities across all levels of current and aspiring CI research communities and institutions. Our analysis revealed issues and proactive activities in CI communities at all levels ranging from R1 institutions to R2 institutions, PWIs to HBCUs, TCUs, HSIs, and other MSIs, and even across EPSCoR jurisdictions. But we are also reminded that in 2022 we are still challenged with gender and race inequality. And some of us were surprised about the lack of leadership development for CI professionals.

Our synthesis of the reports from the contributors has identified the following needs:

- **Professionalization**
  Build a professionalized CI workforce with well-defined career paths within universities, government labs, and other related settings, as well as across the broader ecosystem (recognized with relevant titles).

- **Diversity, Equity, & Inclusion**
  Integrate diversity, equity, and inclusion as central to the curriculum and professional development, not just as an assessment metric for workforce development programs. There is a need to build a diverse workforce coming from diverse disciplines with diverse skill sets from and for diverse institutions (institutions from all classifications).

- **Community Building**
  Include community-building efforts across the entire CI ecosystem spectrum to increase expertise, capability, and capacity at underrepresented institutions to support science and research. These will need to be agile and adaptive collaborations, given the accelerating pace of change with technology and the many complex challenges in society (Stakeholder Alignment Collaborative, 2022).

- **Intentional Seed Planting**
  Include "Front-end" efforts to make contact, and develop intentional relationships to recruit, encourage, and support new diverse people to choose CI pathways (including both underrepresented communities and underrepresented institutions).

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4.0   RECOMMENDATIONS

THE WORKFORCE DEVELOPMENT WORKING GROUP OFFERS THESE RECOMMENDATIONS.

1. Increased Access

Provide increased access to science and engineering programs and resources to develop the next-generation workforce. As a precursor to that, significant additional programmatic efforts are required to increase the expertise and experience of the workforce to effectively engage in science and engineering.

2. Broader Engagement

Invest in broader engagement programs and approaches to build and expand a diverse workforce, including targeted apprenticeships, internships, work-study programs, and fellowships. Invitations need to be extended from significant science projects and conferences to underrepresented students and faculty to directly engage, participate in, and lead the conduct of science and engineering research.

3. Underrepresented Community Development

Develop science and research communities with underrepresented institutions and communities to broaden the workforce. Students, faculty, and staff need to work with others in their science and engineering communities to obtain a sense of belonging and become vital contributing members of the workforce.